IS 8441 (1977): Methods of measurement on incidental X-radiation from electron tubes [LITD 4: Electron Tubes and Display Devices]

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# Indian Standard

# METHODS OF MEASUREMENTS ON INCIDENTAL X-RADIATION FROM ELECTRON TUBES

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## 0. FOREWORD

**0.1** This Indian Standard was adopted by the Indian Standards Institution on 26 April 1977, after the draft finalized by the Electron Tubes Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

**0.2** This standard deals with measuring methods on incidental X-radiation from electron tubes.

**0.3** While preparing this standard, assistance has been derived from the following documents issued by International Electrotechnical Commission:

39 ( C. O. ) 261 Draft — Measurements of incidental ionizing radiation from electron tubes

39 ( C. O. ) 280 Draft — Amendments to Doc: 39 ( C. O. ) 261

39 ( C. O. ) 285 Report on the voting under the Two Months' Procedure for the approval of Doc: 39 ( C. O. ) 280

**0.4** In reporting the result of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

## 1. SCOPE

**1.1** This standard describes methods for the detection of X-radiation and for the direct and indirect measurement of field pattern and exposure rate of random incidental radiation emanating from high voltage electron tubes. This does not include maximum permissible levels for radiation safety.

## 2. TERMINOLOGY

**2.0** For the purpose of this standard the terms and definitions given in IS : 1885 ( Part IV/Sec 1 )-1973† shall apply in addition to the following.

*Rules for rounding off numerical values ( *revised* ).

†Electrotechnical vocabulary: Part IV Electron tubes, Section 1 Common terms ( *first revision* ).

**2.1 Enclosure** — The accessible outer surface of the electron tube including stated parts of the microwave connecting circuits or an arbitrary but stated surface used for reference in the measurement.

NOTE — For example *see* Fig. 1, 2 and 3.

**2.2 Detector Aperture** — The cross-sectional area of the radiation sensitive volume of the detector.

**2.3 Detector Reference Plane ( or Axis )** — The plane ( or axis ) of the radiation sensitive volume of the detector with respect to which ( plane or axis ) the detector is calibrated.

**2.4 Radiation Energy** — The energy of the photons constituting radiation. It is usually expressed in kiloelectronvolt ( keV ).

## 3. THEORY

**3.1** Whenever high velocity electrons strike a material, X-rays are produced. The spectral energy distribution of the radiation is a function of the accelerating voltage, while the exposure rate at constant current, varies as the second power of the voltage. This is true for the radiation at the ' target '. Selective filtering of the X-radiation by the tube envelope and/or internal components may cause the exposure rate external to the tube to vary as a larger exponent of the voltage.

**3.1.1** When the filtering is minimal, the exponent remains two. When the filtering is extensive, high values of the exponents can be expected. For example, in the TV picture tube, the exponent may be as high as 30.

## 4. APPARATUS REQUIREMENTS

**4.1 Portable Exposure-Rate Meter** — An exposure-rate meter ( properly shielded against electromagnetic radiation other than X-radiation ) for probing or rapid surveying of a radiation field. This meter, of the ionization chamber type with a thin window and with a specified detector aperture, is intended to be the principal measuring instrument.

NOTE — Other detectors of low energy X-radiation may also be used, such as Geiger-Muller counters, proportional gas detectors, scintillation and semiconductor detectors, provided that the calibration is known over the energy ranges being measured and differences in detector apertures are considered.

**4.2 Film Mount** — A holder for X-ray sensitive film which has been designed to shield the film from exposure to light ( and heat and oil if necessary ).

NOTE — The mount often includes a series of thicknesses of aluminium so that an expert, for example, from personnel monitoring film badge service using a densitometer and prior calibration data and energy response of the film, can estimate the effective energy and intensity.

**4.3 Power Supply** — The source which provides stable conditions for operation of the tube and has means for measurement of anode voltage and current shall be used.

**4.3.1** A high voltage meter is required for measurement of the high voltage with a stated accuracy, usually 0·5 percent for dc, 1 percent for ac and 2 percent for pulse voltage measurement. The meter shall be calibrated using a high voltage divider with suitable accuracy and stability.

**4.3.2** Current meter for measurement of the current with less than 2 percent error shall be used.

## 5. CALIBRATION

**5.1** The exposure-rate meter or film mount shall be calibrated by a known X-ray field with an exposure rate and effective radiation energy approximately equal to the measured values. It is to be noted that the actual electron velocities may be those associated with approximately twice the applied voltage. The effective radiation energy of the measured and known X-ray fields shall be determined by application of half value layers according to Table 1.

When measuring shunt regulators, high voltage rectifiers and cathode-ray tubes the effective energy of the X-rays may be determined by the value of the voltage to be applied for the measurement with the limitations due to selective filtering ( *see* **3** ).

The calibrating exposure rate shall be representative of the exposure rate to be measured. This calibration shall be traceable to a suitable primary standard.

**TABLE 1 HALF VALUE LAYERS**

( *Clause* 5.1 )

| Effective Energy | Material | Half Value Layer |
|---|---|---|
| (1) | (2) | (3) |
| keV | | mm |
| 7 | Aluminium | 0·1 |
| 21 | Aluminium | 0·9 |
| 23 | Aluminium | 1·1 |
| 35 | Aluminium | 3·3 |
| 50 | Aluminium | 6·6 |
| 50 | Copper | 0·3 |
| 80 | Copper | 1·0 |
| 100 | Copper | 1·4 |
| 130 | Copper | 2·7 |
| 160 | Copper | 3·9 |
| 200 | Copper | 5·0 |
| 200 | Lead | 0·7 |
| 265 | Lead | 1·25 |
| 300 | Lead | 1·8 |

**5.2** An appropriate radioactive source is a convenient means of checking the stability of the calibration.

**5.3** The instrument to be used to make the measurement shall be calibrated over the range of energy levels of the known radiation and shall have the required detector aperture.

NOTE — The detector aperture is normally given in $cm^2$ with a further restriction on the major dimensions.

## 6. MEASUREMENT CONDITIONS

**6.1 General** — Measurements of X-radiation arising from the operation of electron tubes are generally separable into two categories as given below:

a) Initial or general surveys, and

b) Measurements on products having known radiation patterns.

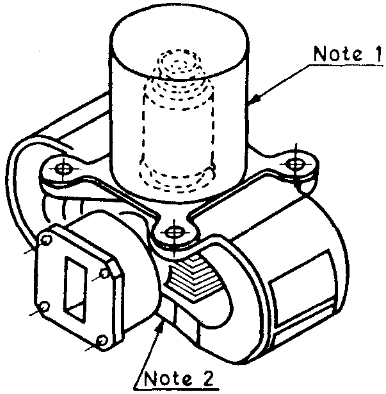
In making surveys, especially initial surveys, it is important that no assumptions shall be made regarding the nature of the field pattern to be expected since changes in tube materials at junctions or the presence of very sharply defined secondary electron beams may often give rise to sharply defined X-ray beams from very unexpected places. Thus, it is often found practical to make such surveys with film techniques so that complete patterns, even of very sharply defined beams may be measured. The effective energy of the X-rays emitted in the direction of maximum exposure rate shall be measured by the initial survey.

When the radiation pattern is known, the tube being measured shall be positioned relative to the measurement equipment so that measurements will be made at the point where maximum radiation is observed. A suitable warm-up period shall be provided before initiating measurements so that measurement apparatus and the tube being measured are operating at stable stated conditions.

Reading from instruments having smaller detector apertures may be used provided many measurements are made, traversing the area of interest, to permit integration to correct for spatial non-uniformity of field. Detectors having larger apertures should only be used when the field of radiation is known to be uniform across the aperture.

**6.2 Enclosure** — The tube to be measured shall be within the stated enclosure ( *see* Fig. 1, 2 and 3 ).

**6.3 Shunt Regulators** — The tube being measured shall be operated at the rated maximum high dc anode ( not supply ) voltage and current, which shall not vary ( including ripple ) or drift more than $\pm$ 0·5 percent in voltage, and $\pm$ 2 percent in current during the entire measurement period. If the combination of rated maximum dc anode voltage and




NOTE 1 — Cathode well is not normally part of the enclosure.
NOTE 2 — Exhaust tubulation area is very suspect since the metal is thin.

FIG. 1 TYPICAL ENCLOSURE FOR PULSE MAGNETRON

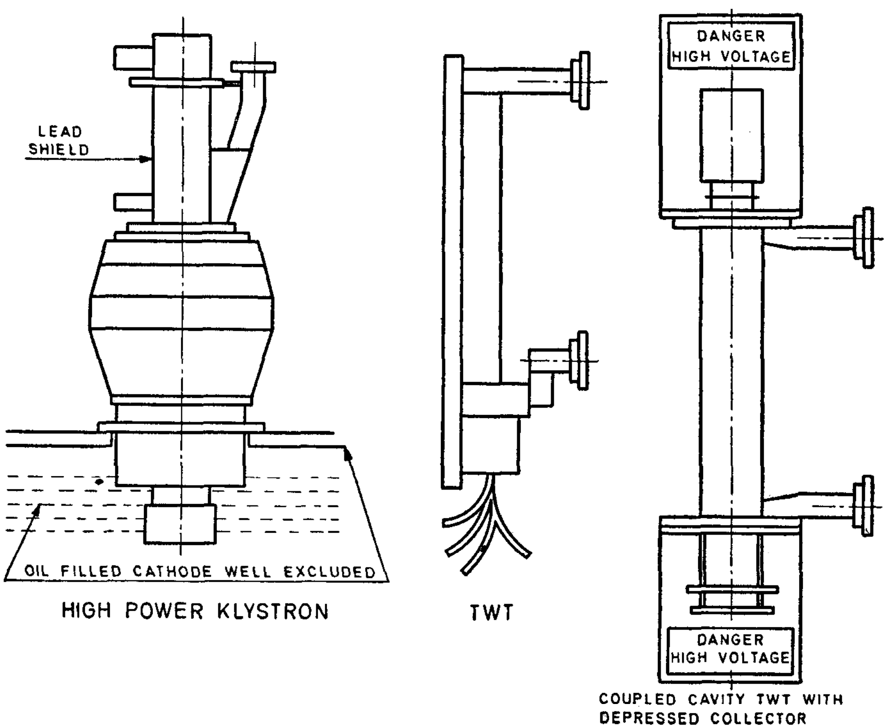
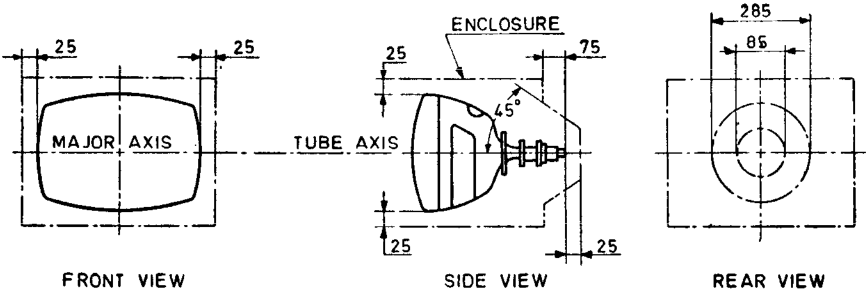



FIG. 2 TYPICAL X-RAY ENCLOSURES




All dimensions in millimetres.

FIG. 3 TYPICAL ENCLOSURE FOR CATHODE-RAY TUBES

current produces a dissipation value in excess of the tube rated maximum anode dissipation, the current shall be reduced by an amount such that this dissipation value is acquired without reduction of the rated dc anode voltage.

**6.4 High Voltage Rectifiers** — The method described in **6.4.1** is required only if the anode emits in the inverse voltage phase due to hot spots or field emission.

Where these problems do not arise, the method described in **6.4.2** may be used.

**6.4.1** *Operational Measurements* — An ac potential corresponding to the limiting value of the peak inverse voltage will be applied to cathode or filament relative to the anode. Peak to peak voltage regulation shall be within the stated limits. The power supply and load impedance shall be chosen to result in operation at:

a) maximum rated peak current, or

b) maximum rated anode dissipation, or

c) both.

**6.4.2** *Inverse Measurements* — A positive dc potential, corresponding to the rated maximum peak inverse voltage (total dc and peak), will be applied to the cathode or filament relative to the anode. This voltage including ripple shall not vary or drift more than $\pm$ 0·5 percent during the entire measurement period. It is not necessary to energize the heater or filament during this measurement.

**6.5 Cathode-Ray Tubes**

**6.5.1** The tube being measured shall be operated at the stated anode voltage, anode current, and optimum focus voltage. The anode voltage

shall not vary or drift more than ± 0·5 percent during the entire measurement period. For multiple gun tubes, approximately equal beam currents shall be used.

NOTE — To meet this requirement, the anode power supply shall have an internal impedance not greater than the stated value.

**6.5.2** The scanning controls shall be adjusted to produce a stated raster.

**6.6 Transmitting and Modulator Tubes** — The tube shall be operated under stated operating conditions within the maximum limiting conditions.

It is to be noted that the actual electron velocities may be those associated with approximately twice the applied voltage.

**6.7 Microwave Tubes**

**6.7.1** The tube shall be operated at the stated typical operating conditions.

**6.7.2** It is recommended that tubes shall also be measured under stated abnormal conditions as to increase the likelihood of emission of X-radiation, without, however, causing damage to the tube.

It is to be noted that the actual electron velocities may be those associated with approximately twice the applied voltage.

NOTE — The normal precautions shall be taken to prevent exposure to microwave radiation.

## 7. MEASUREMENTS

**7.1** The tube shall be operating in conformity with measurement conditions as given in **6**.

**7.2 Measurements Using X-Ray Films** — X-ray films covering the entire enclosure may be used to define the source, evaluate the relative intensity, and determine the pattern of the X-radiation.

NOTE 1 — It is recommended X-ray films be used on initial surveys to determine the point of greatest exposure rate for latter measurement with portable exposure-rate meters.

NOTE 2 — This method may also be the only one to use when measuring radiation from very high power tubes which normally are not fully shielded as shipped and which may in part, at least, operate under oil.

**7.3 Measurements Made Using Survey Meter** — Explore the total surface of the enclosure with the detector reference plane at a stated distance ( namely, 5 cm ) from the enclosure and proceed sufficiently slowly so as to allow the indicator to respond to sharp beams.

The measurement shall be made at the location of maximum exposure rate.

At least three successive readings shall be taken for each survey meter position, the average value being recorded.

The background radiation shall be verified at the measurement position before and after the exposure period and corrections applied to observed data as required.

## 8. PRECAUTIONS

**8.1** X-radiation emitted by high power tubes may have large exposure rates.

Under certain circumstances protective coating on X-ray films ( *see* **7.2** ) may be required to withstand heat or immersion in liquid.

**8.2** Assign film badges and dosimeters to all personnel involved in survey operations.

**8.3** The measuring instrument shall be thoroughly grounded to avoid shock hazard.

**8.4** The presence of radio frequency energy at high level may cause irregular readings or apparently high background. Whenever abnormally high readings are observed, it shall be verified that they are not caused by non-ionizing fields.

**8.5** The measurements facility shall include such shielding as to reduce operator hazard to far less than the acceptable level from X-radiation and from the high voltages normally associated with tubes being measured.

## 9. REPORTING

**9.1** It shall be expressed in milliröentgen per hour ( mR/hour ).

**INDIAN STANDARDS**

**ON**

**ELECTRON TUBES**

IS:

1885 ( Part IV/Sec 1 )-1973 Electrotechnical vocabulary: Part IV Electron tubes, Section 1 Common terms (*first revision* )

1885 ( Part IV/Sec 2 )-1973 Electrotechnical vocabulary: Part IV Electron tubes, Section 2 X-ray tubes (*first revision* )

1885 ( Part IV/Sec 3 )-1970 Electrotechnical vocabulary: Part IV Electron tubes, Section 3 Microwave tubes

1885 ( Part IV/Sec 4 )-1970 Electrotechnical vocabulary: Part IV Electron tubes, Section 4 Cathode ray tubes

1885 ( Part IV/Sec 5 )-1972 Electrotechnical vocabulary: Part IV Electron tubes, Section 5 Pulse terms

1885 ( Part IV/Sec 6 )-1972 Electrotechnical vocabulary: Part IV Electron tubes, Section 6 Noise in microwave tubes

1885 ( Part IV/Sec 7 )-1973 Electrotechnical vocabulary: Part IV Electron tubes, Section 7 Camera tubes

1885 ( Part IV/Sec 8 )-1973 Electrotechnical vocabulary: Part IV Electron tubes, Section 8 Photosensitive devices

2032 ( Part IX )-1969 Graphical symbols used in electrotechnology: Part IX Electron tubes ( other than microwave tubes )

2032 ( Part XIII )-1971 Graphical symbols used in electrotechnology: Part XIII Microwave tubes

2597 ( Part I )-1964 Code of practice for the use of electron tubes: Part I Commercial receiving tubes

2597 ( Part II )-1967 Code of practice for the use of electron tubes: Part II Special quality receiving tubes

2597 ( Part III )-1969 Code of practice for the use of electron tubes: Part III Transmitting and industrial tubes

2597 ( Part IV )-1970 Code of practice for the use of electron tubes: Part IV Cathode ray tubes

2597 ( Part V )-1971 Code of practice for the use of electron tubes: Part V Rectifiers and thyratrons

2612-1965 Recommendation for type approval and sampling procedures for electronic components

2684 ( Part I )-1972 Dimensions of electron tubes: Part I Miniature '9-pin noval' type (*first revision* )

2684 ( Part II )-1972 Dimensions of electron tubes: Part II Miniature '7-pin type' (*first revision* )

2684 ( Part III )-1971 Dimensions of electron tubes: Part III Octal base type

2684 ( Part IV )-1971 Dimensions of electron tubes: Part IV Magnoval base type

2684 ( Part V )-1972 Dimensions of electron tubes: Part V Loctal base type

3154-1965 Specification for X-ray tubes, diagnostic type

4096-1973 Method of measurement of optical focal spot size of X-ray tubes (*first revision* )

4147-1967 Method of measurements on conventional receiving electron tubes

4579-1968 Method of measurements on television picture tubes

4697-1968 Method of measurements on Geiger Muller counter tubes

5323-1969 Letter symbols and abbreviations for electron tubes

5627-1970 Methods of measurements on cathode-ray display tubes

5840 ( Part I )-1970 Dimensions of cathode-ray tubes: Part I Tube outlines

5840 ( Part II )-1970 Dimensions of cathode-ray tubes: Part II Bases

5840 ( Part III )-1970 Dimensions of cathode-ray tubes: Part III EHT terminals

6134 ( Part I/Sec 1 )-1971 Methods of measurement on microwave tubes: Part I General measurements, Section 1 General conditions and precaution for measurements

6134 ( Part I/Sec 2 )-1972 Methods of measurement on microwave tubes: Part I General measurements, Section 2 Common to all devices

6134 ( Part II )-1973 Methods of measurement on microwave tubes: Part II Oscillator tubes

6134 ( Part III )-1973 Methods of measurement on microwave tubes: Part III Amplifier tubes

6134 ( Part IV )-1977 Methods of measurement on microwave tubes: Part IV Magnetrons

6136-1971 Basic requirements for cathode ray tubes

6214-1971 Phosphors for cathode ray tubes

6567-1972 Radiation protection for an X-ray tube in a protective tubehousing, operating between 10 kV and 400 kV

6568-1972 Implosion protection for TV picture tubes

6576-1972 Methods of measurements on gas filled cold cathode indicator tubes

6577-1972 Methods of measurements on gas filled cold cathode voltage stabilizing and voltage reference tubes

6757-1972 Dimensions for high tension cable terminations for X-ray tubes

6758-1972 Dimensions for high tension receptacles for X-ray tubes

7012-1973 Specification for X-ray tube shield

7144-1973 Methods of measurements on camera tubes

7146 ( Part I )-1973 Methods of measurements on photosensitive devices: Part I Basic considerations

7146 ( Part II )-1974 Methods of measurements on photosensitive devices: Part II Photo-tubes

7146 ( Part III )-1974 Methods of measurements on photosensitive devices: Part III Photoconductive cells for use in the visible spectrum

7146 ( Part IV )-1974 Methods of measurements on photosensitive devices: Part IV Photomultipliers

8319 ( Part I )-1977 Dimensions of indicator tubes: Part I Tube type 1

8319 ( Part II )-1977 Dimensions of indicator tubes: Part II Tube type 2

8319 ( Part III )-1977 Dimensions of indicator tubes: Part III Tube type 3

# INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

## Base Units

| *Quantity* | *Unit* | *Symbol* |
|---|---|---|
| Length | metre | m |
| Mass | kilogram | kg |
| Time | second | s |
| Electric current | ampere | A |
| Thermodynamic temperature | kelvin | K |
| Luminous intensity | candela | cd |
| Amount of substance | mole | mol |

## Supplementary Units

| *Quantity* | *Unit* | *Symbol* |
|---|---|---|
| Plane angle | radian | rad |
| Solid angle | steradian | sr |

## Derived Units

| *Quantity* | *Unit* | *Symbol* | *Conversion* |
|---|---|---|---|
| Force | newton | N | 1 N = 1 kg.1 m/s$^2$ |
| Energy | joule | J | 1 J = 1 N.m |
| Power | watt | W | 1 W = 1 J/s |
| Flux | weber | Wb | 1 Wb = 1 V.s |
| Flux density | tesla | T | 1 T = 1 Wb/m$^2$ |
| Frequency | hertz | Hz | 1 Hz = 1 c/s (s$^{-1}$) |
| Electric conductance | siemens | S | 1 S = 1 A/V |
| Pressure, stress | pascal | Pa | 1 Pa = 1 N/m$^2$ |